

US007901641B2

(12) **United States Patent**  
**Kumar et al.**

(10) **Patent No.:** **US 7,901,641 B2**  
(45) **Date of Patent:** **Mar. 8, 2011**

(54) **SPRAYER FOR AT LEAST ONE FLUID**

(75) Inventors: **Sailesh B. Kumar**, Naperville, IL (US);  
**Richard S. Hatami**, Inverness, IL (US);  
**Robert Crismyre**, Park Ridge, IL (US)

(73) Assignee: **UOP LLC**, Des Plaines, IL (US)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 387 days.

(21) Appl. No.: **12/177,793**

(22) Filed: **Jul. 22, 2008**

(65) **Prior Publication Data**

US 2010/0019061 A1 Jan. 28, 2010

(51) **Int. Cl.**

**B01D 19/00** (2006.01)  
**B01J 8/00** (2006.01)  
**C10G 9/18** (2006.01)

(52) **U.S. Cl.** ..... **422/220**; 95/149; 95/158; 422/224;  
422/191; 422/194; 422/195; 261/96; 261/97;  
261/110; 261/114.1; 210/97; 210/137

(58) **Field of Classification Search** ..... 95/149,  
95/158, 185; 422/191, 194, 195, 220, 224;  
261/96, 97, 110, 114.1; 210/97, 137  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

3,378,349 A \* 4/1968 Shirk ..... 422/194  
3,524,731 A \* 8/1970 Effron et al. .... 422/220  
3,542,731 A \* 11/1970 Culbertson ..... 528/170  
4,313,908 A 2/1982 Gupta

4,836,989 A 6/1989 Aly et al.  
4,952,302 A 8/1990 Leach  
5,158,714 A 10/1992 Shih et al.  
5,242,577 A 9/1993 Betts et al.  
5,403,560 A 4/1995 Deshpande et al.  
5,688,445 A 11/1997 Wrisberg  
5,918,637 A \* 7/1999 Fleischman ..... 138/44  
6,123,323 A \* 9/2000 Yoneda et al. .... 261/96  
6,371,454 B1 \* 4/2002 Gerla et al. .... 261/114.1  
6,669,915 B1 12/2003 Boyd et al.  
6,769,672 B2 8/2004 Müller  
6,984,365 B2 1/2006 Nelson et al.  
7,032,894 B2 4/2006 Adusei et al.  
7,112,312 B2 9/2006 Chou  
7,452,516 B2 \* 11/2008 Van Hasselt et al. .... 422/311  
2005/0077635 A1 4/2005 Van Hasselt et al.

**FOREIGN PATENT DOCUMENTS**

EP 0207673 A1 1/1987  
WO WO-2007/124328 A2 11/2007

**OTHER PUBLICATIONS**

Swain et al., Getting the Maximum from Hydroprocessing Reactors, PTQ, Autumn 2001, pp. 37-43.

\* cited by examiner

*Primary Examiner* — Walter D Griffin

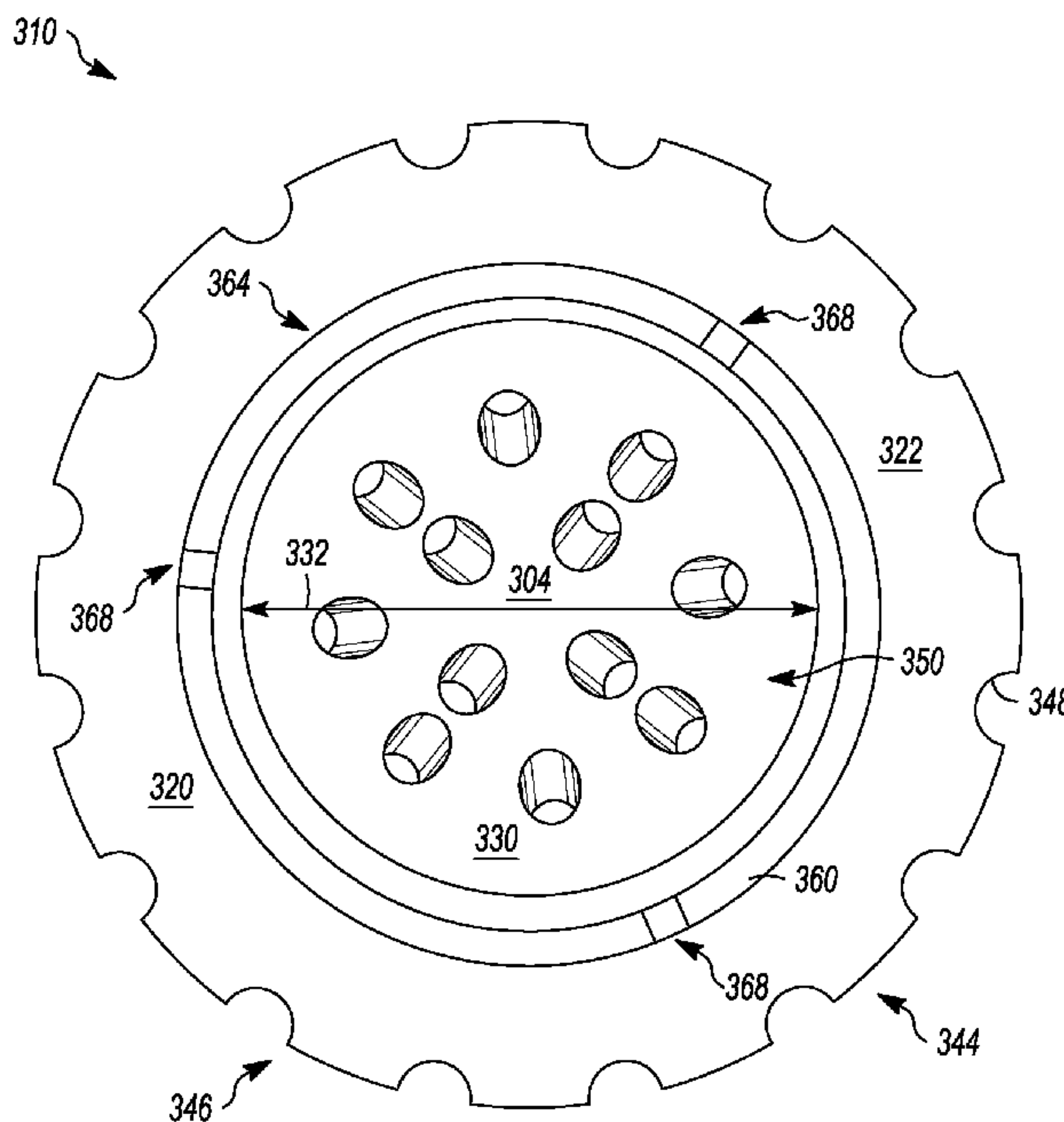
*Assistant Examiner* — Huy-Tram Nguyen

(74) *Attorney, Agent, or Firm* — Mark Goldberg

(57) **ABSTRACT**

One exemplary embodiment can be a sprayer for distributing at least one fluid in a vessel. The sprayer can include a first member having a first surface and a second surface forming at least one aperture there-through. Generally, the at least one aperture is skewed with respect to a substantially vertical axis passing through a center of the first member for distributing the at least one fluid in the vessel.

**9 Claims, 6 Drawing Sheets**



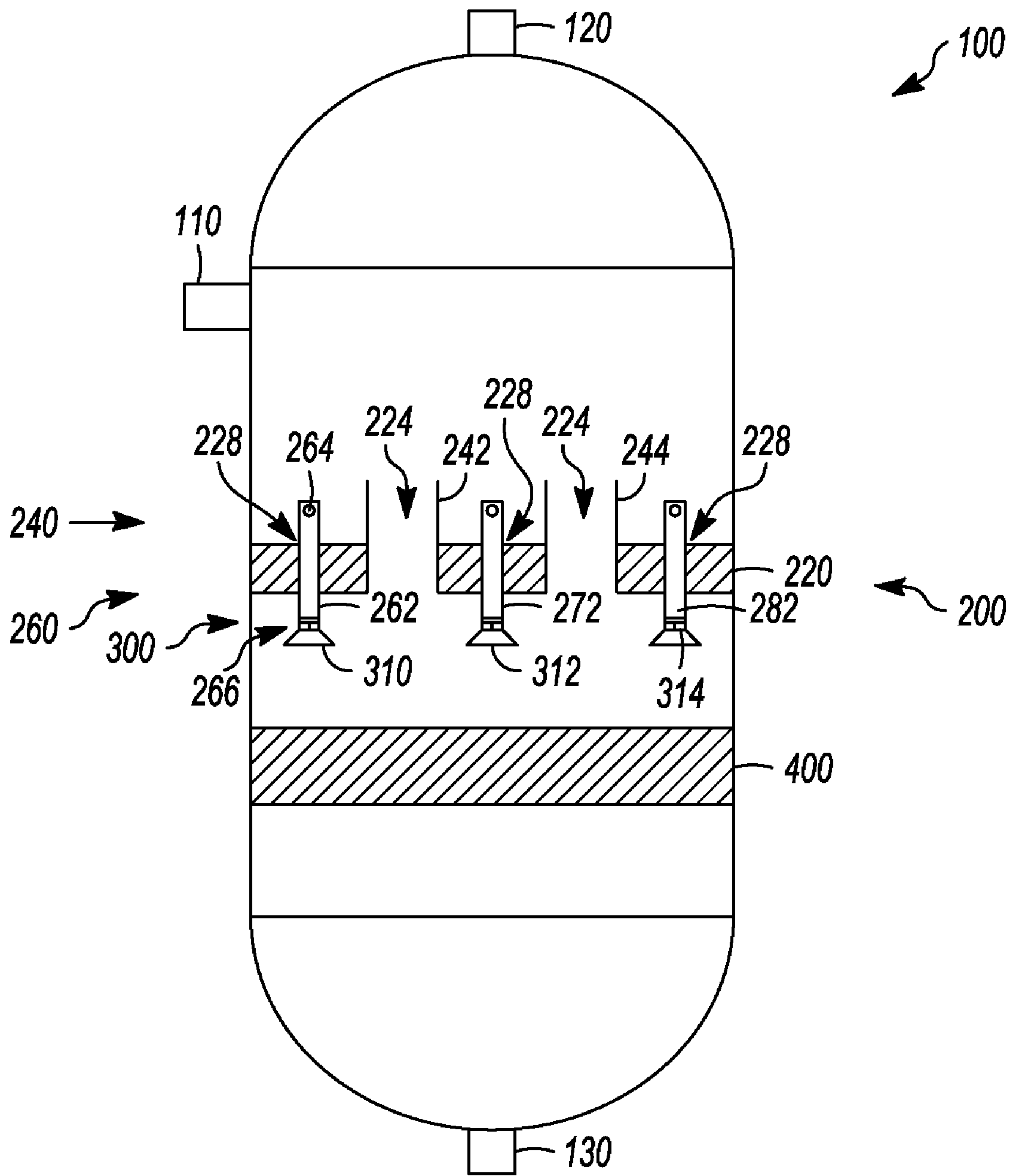
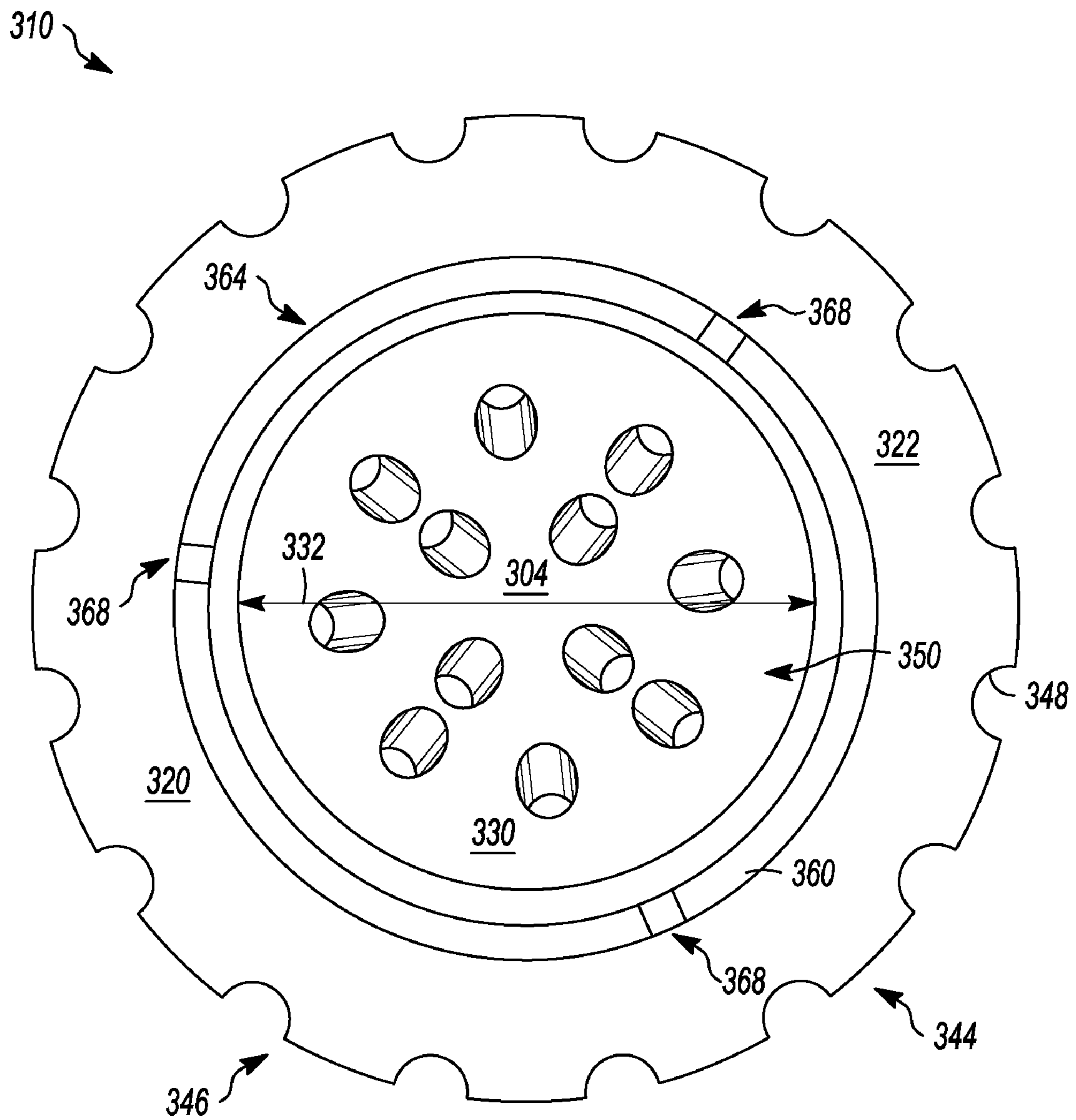
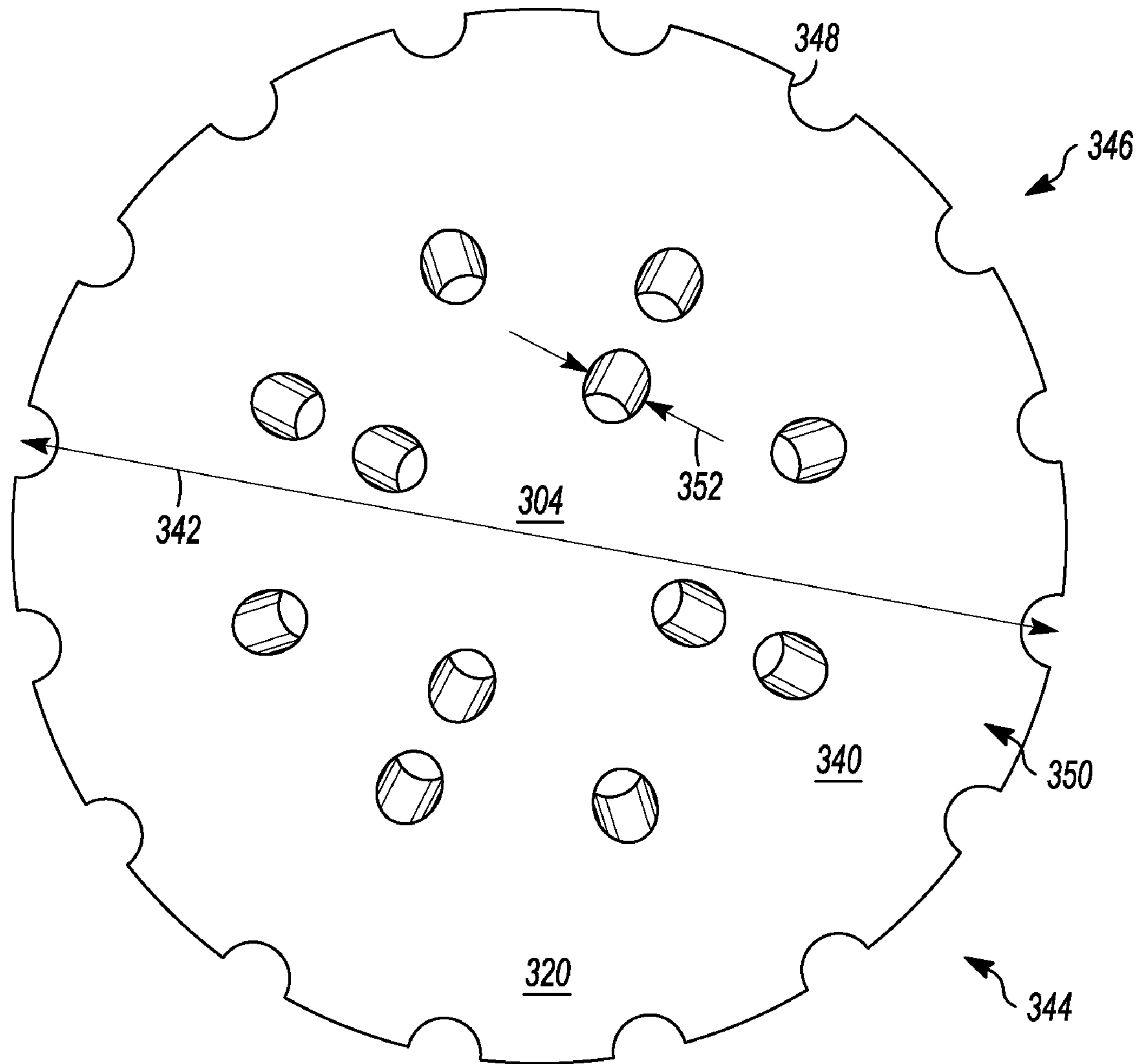


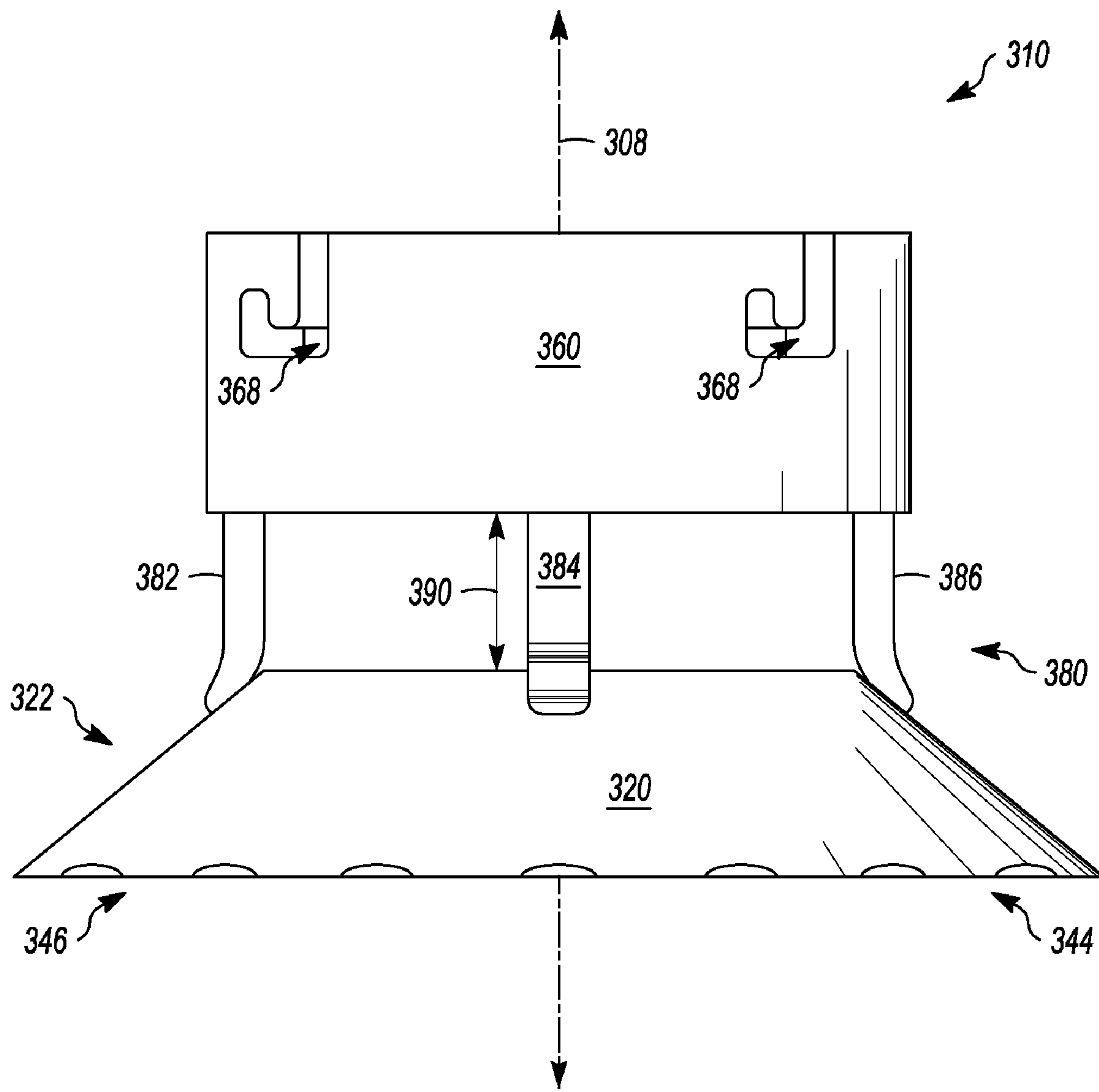
FIG. 1



**FIG. 2**



**FIG. 3**



**FIG. 4**

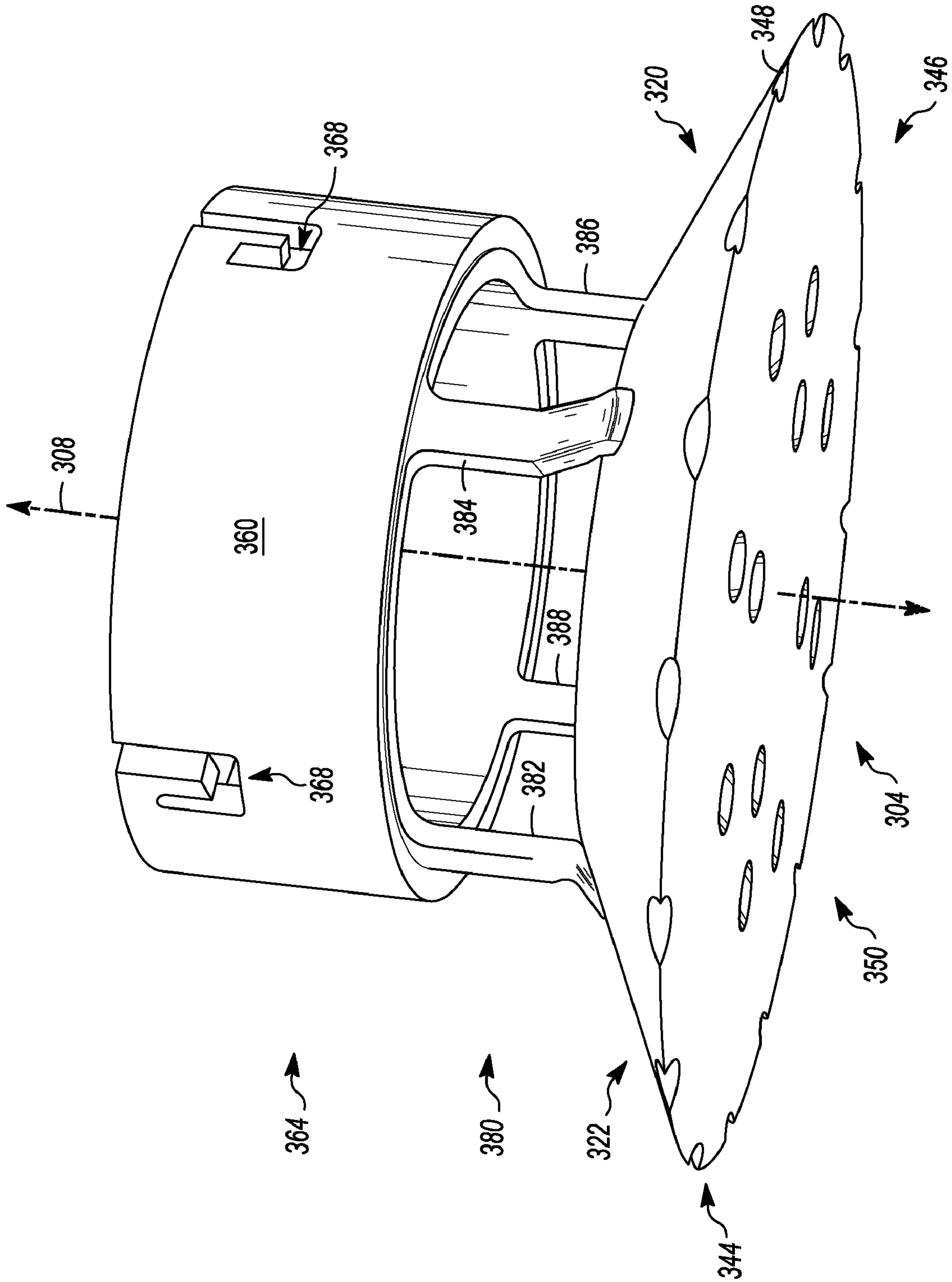
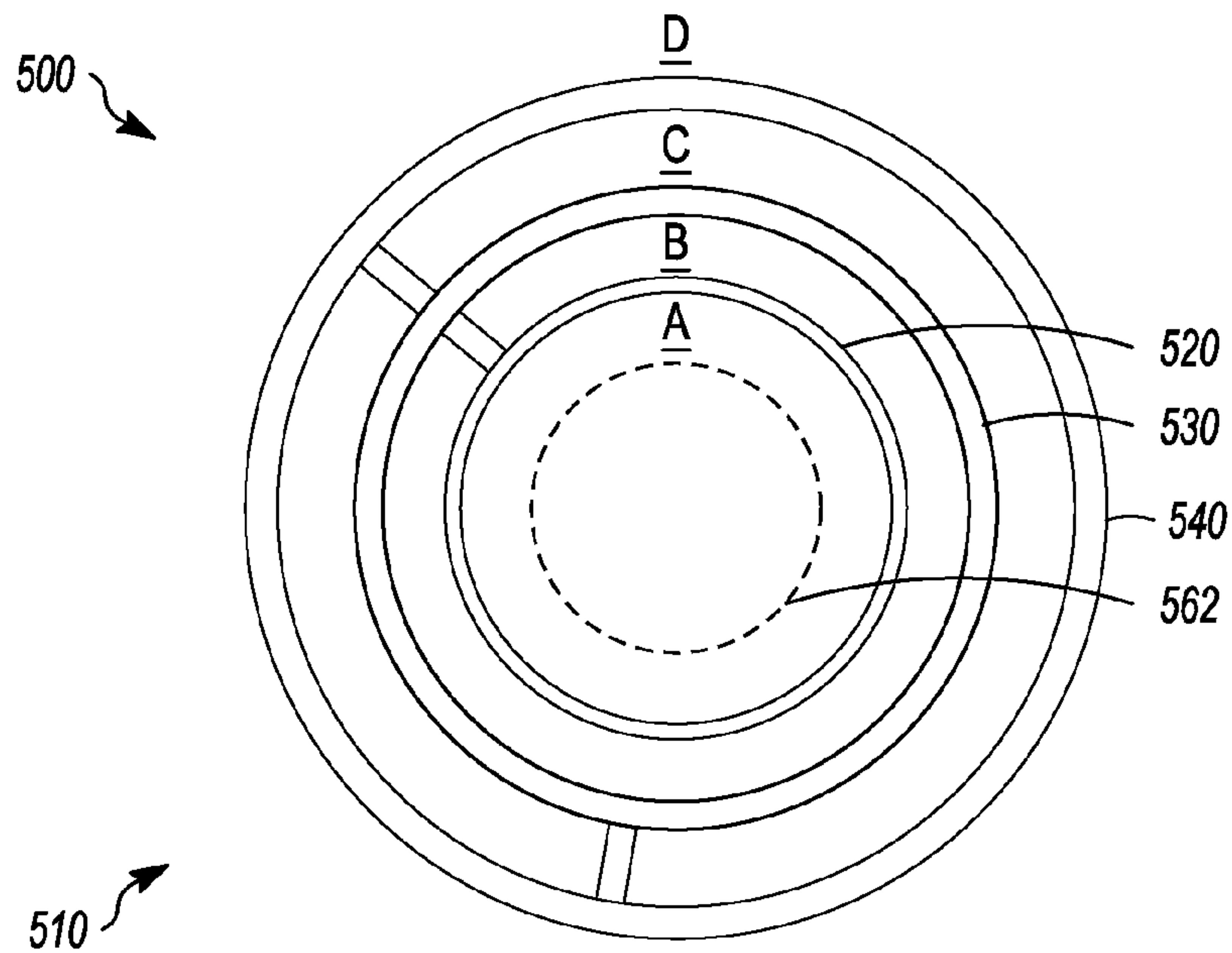
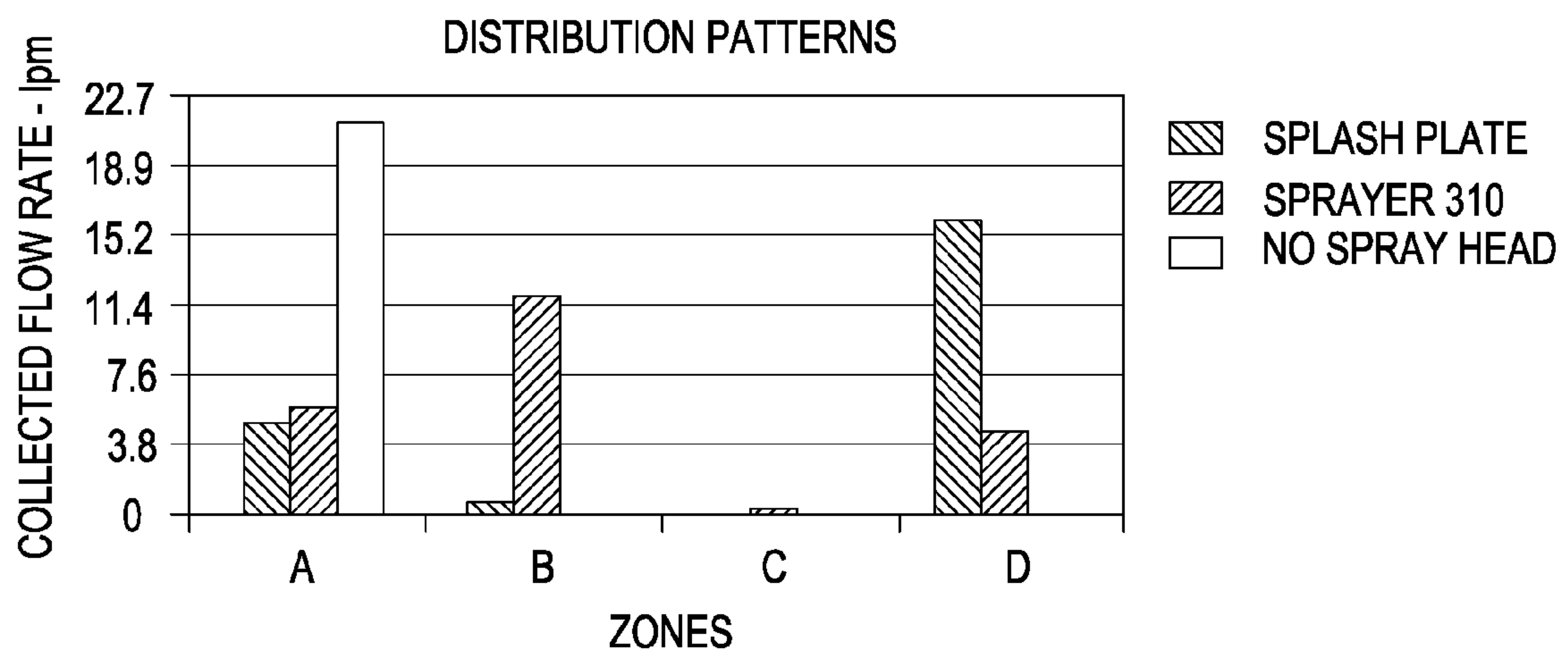


FIG. 5





**FIG. 6**



**FIG. 7**

1

**SPRAYER FOR AT LEAST ONE FLUID**

## FIELD OF THE INVENTION

The invention generally relates to a sprayer for at least one fluid.

## DESCRIPTION OF THE RELATED ART

Various vessels can be used in chemical processing, petroleum refining, and other industries for distributing fluids, particularly a mixed-phase fluid of liquid and gas over beds or trays. One particular vessel can be a reactor, such as a trickle flow reactor, that can be used in processes such as catalytic dewaxing, hydrotreating, hydrodesulfurization, hydrofinishing, and hydrocracking. Generally, a feed, such as a fluid including one or more liquids and gases, can pass over a particulate catalyst contained in a packed bed in a downflow reactor. Chemical reactions can take place that may produce additional components in a gas phase, such as hydrogen sulfide and ammonia, in some hydrotreating processes. Such gases may separate from the liquid and rise to the top of the reactor to exit at an upper outlet. The liquid typically flows downward through the packed bed and exits a bottom outlet.

To facilitate reactions, a solid catalyst is often arrayed in a plurality of beds with a distributor plate or tray above each bed for the purpose of uniformly, effectively, and efficiently distributing the fluid at the top of the bed.

Generally, trays can be provided with distributors to provide an equally divided flow across the underlying bed. However, these distributors can suffer from shortcomings when, for example, ideal conditions are not presented and an unequal distribution of liquid occurs. As an example, non-ideal distribution conditions can exist during the start-up of a unit, e.g., after maintenance is conducted. These non-ideal conditions can lead to an inefficient wetting of the catalyst bed below the distributor. This uneven wetting can create hotspots in the catalyst bed leading to one or more pockets of shortened catalyst life. In addition, an uneven flow of liquid can create channeling through the bed. As a consequence, it is desirable to provide a distributor that provides better and consistent wetting of the underlying catalyst bed to avoid these shortcomings and extend the catalyst life.

## SUMMARY OF THE INVENTION

One exemplary embodiment can be a sprayer for distributing at least one fluid in a vessel. The sprayer can include a first member having a first surface and a second surface forming at least one aperture there-through. Generally, the at least one aperture is skewed with respect to a substantially vertical axis passing through a center of the first member for distributing the at least one fluid in the vessel.

Another exemplary embodiment can be a vessel for distributing at least one fluid. The vessel may include a distributor and a packed bed including a plurality of particles positioned below the distributor. In addition, generally the distributor includes a tray forming at least one void, a conduit coupled to the tray about the void and passing there-through; and a sprayer coupled proximate to a bottom end of the conduit. Furthermore, the sprayer may include a first member forming a plurality of diverging apertures there-through, and having a first surface and a second surface.

A further exemplary embodiment may be a process for distributing at least one hydrocarbon fluid. The process can include passing the at least one hydrocarbon fluid through a conduit to a sprayer. What is more, the sprayer can include a

2

first member forming a plurality of diverging apertures, and having a first surface and a second surface.

The embodiments disclosed herein can provide a sprayer that can prevent hot spots and channeling in a packed bed by providing a consistent and sufficient liquid distribution. The sprayer can have several design features that can be adapted to provide a suitable spray for a particular vessel. As such, multiple sprayers may provide overlap and redundancy should a sprayer become inoperable by, e.g., plugging. In addition, the increased effectiveness of the sprayer can reduce the number of sprayers required for a particular vessel. Thus, the improved sprayer may extend catalyst life by preventing hot spots or channeling that can reduce the life of the catalyst and/or make the reactor less effective.

## DEFINITIONS

As used herein, the term "fluid" can mean one or more gases and/or one or more liquids.

As used herein, the term "gas" can mean a single gas or a solution of a plurality of gases. In addition, the term "gas" may include a solution or a suspension, e.g., a vapor or an aerosol, of one or more liquid particles and/or one or more solid particles, of the same or different substances, in one or more gases.

As used herein, the term "liquid" can mean a single liquid, or a solution or a suspension of one or more liquids with one or more gases and/or solid particles.

As used herein, the terms "absorbent" and "absorber" include, respectively, an adsorbent and an adsorber, and relates, but is not limited to, absorption, and/or adsorption.

As used herein, the term "rich" can mean an amount generally of at least about 50%, and preferably about 70%, by mole, of a compound or class of compounds in a stream.

As used herein, the term "perimeter" generally means a boundary of an object or region, and can be of any suitable shape, such as a circle, oval, square, diamond, rectangle, or irregular.

As used herein, the term "coupled" can mean two items, directly or indirectly, joined, fastened, associated, connected, or formed integrally together either by chemical or mechanical means, by processes including stamping, molding, or welding. What is more, two items can be coupled by the use of a third component such as a mechanical fastener, e.g. a screw, a nail, a staple, or a rivet; an adhesive; or a solder.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational, side view of an exemplary vessel.

FIG. 2 is a top, plan view of an exemplary sprayer.

FIG. 3 is a bottom, plan view of the exemplary sprayer.

FIG. 4 is a side, elevational view of the exemplary sprayer.

FIG. 5 is an elevational, side view of the exemplary sprayer.

FIG. 6 is a schematic, top, and plan view of an exemplary collection device.

FIG. 7 is a graphical depiction comparing distribution patterns.

## DETAILED DESCRIPTION

Referring to FIG. 1, a vessel 100 is depicted having an inlet 110, a first outlet 120, and a second outlet 130. The vessel 100 can receive a feed. The feed can be a fluid, including a liquid or a mixed-phase fluid, such as one or more liquids and gases, through the inlet 110. Generally, the vessel can distribute the feed in the vessel containing a fixed bed of particles, such as a catalyst. Although a reactor is disclosed herein, it should be



understood that other types of vessels such as an absorber or a mass transfer vessel can also use the embodiments disclosed herein, and other materials can be contained instead of or in addition to the catalyst, such as an absorbent.

The vessel **100** can include a distributor **200** and a packed bed **400** of particles, such as a catalyst. The distributor **200** can include a tray **220** forming at least one opening **224** and at least one void **228**. Although only one tray **220** and one packed bed **400** are depicted in this exemplary embodiment, it should be understood that the vessel **100** can contain any number of trays **220** and packed beds **400**. In addition, although a feed is discussed as being distributed, any stream or fluid may be distributed, including intermediate streams internal to the vessel **100** or recycled streams. Generally, the distributor **200** further includes at least one riser **240** and at least one conduit or downcomer **260** that allows the passage of a fluid, such as a liquid or a mixed-phase fluid there-through. In this exemplary embodiment, two risers **240** and three downcomers **260** are depicted, although any number of risers **240** and/or downcomers **260** can be utilized. The at least one riser **240** can include a first riser **242** and a second riser **244** and the at least one downcomer **260** can include a first downcomer **262**, a second downcomer **272**, and a third downcomer **282**. Generally, one or more gases rise through the risers **240**, and one or more fluids, including a fluid rich in one or more liquids, flow downward through the downcomers **260**. The risers **240** and the downcomers **260** may be spaced apart in order to minimize disturbance of a liquid film flow or a spray by interaction with a rising gas flow.

The vessel **100** in exemplary embodiments can be adapted for co-current or counter-current flow. In one exemplary embodiment, the gas and liquid can be in a co-current downward flow, such as a hydrotreating vessel. In such an instance, the risers **240** can be integrated with the downcomers **260** as a single unit, and the gas and liquid can descend to the packed bed **400**. Alternatively, the risers **240** can be omitted and the gas and liquid can flow downward through the downcomers **260**.

As depicted herein, generally the risers **240** surround a respective opening **224** and the downcomers **260** surround a respective void **228** in the tray **220**. The downcomers **260** can include a respective sprayer **300**. Particularly, each downcomer **262**, **272**, and **282** can include a respective first sprayer **310**, a second sprayer **312**, and a third sprayer **314**. Generally, the distribution and density of the downcomers **260** are such that the liquid films or droplet sprays from neighboring downcomers **260** overlap. Therefore, the downcomers **260** are preferably evenly distributed over the tray **220**. As an example, the distributor **200** can have at least 25 downcomers **260** per square meter of tray **220**.

The downcomers **260** and corresponding sprayers **300** can be the same or different, but in this exemplary embodiment each downcomer **260** and each sprayer **300** can be substantially similar to, respectively, other downcomers **260** and sprayers **300**. As such, only downcomer **262** and its respective sprayer **310** are described in greater detail herein.

The downcomer **262** can form an opening **264** and have a bottom end **266**. The downcomer **262** can have a generally tubular or cylindrical shape, but it should be understood that the downcomer **262** can be any suitable shape, such as prism-shaped. Generally, the feed flows from the inlet **110** to the tray **220**, which is substantially horizontal. The liquid collected on the tray **220** can rise and enter the opening **264** and pass downward through the sprayer **310** to the packed bed **400** below the tray **220**.

Referring to FIGS. 1-5, the first sprayer **310** can include a center **304**, a substantially vertical axis **308**, a first member

**320**, a second member **360**, and at least one leg or plurality of legs **380**. Typically, the first member **320** is spaced apart from the second member **360**. The first member **320** can have a shape of a frustum **322** and have a first surface **330** and a second surface **340**. Generally, the first surface **330** and the second surface **340** are substantially parallel, and have respectively, a diameter **332** and a diameter **342**. The second surface **340** can form a perimeter **344**. Generally, the perimeter **344** can be substantially circular **346**, but can be any suitable shape such as rectangular or square. The substantially circular perimeter **346** can form a serrated edge **348** to aid the distribution of, e.g., a feed. However, it should be understood that the serrated edge **348** can take other shapes to aid the distribution of liquid. Typically, the first member **320** forms at least one aperture **350** there-through, preferably a plurality of diverging apertures **350**, with respect to the substantially vertical axis **308**. In this preferred embodiment, the first member **320** forms twelve apertures **350**, although the first member **320** may form any number of apertures **350**. Usually, each aperture **350** can be skewed with respect to the substantially vertical axis **308**, and may be substantially circular and have a diameter **352**. The skewed apertures **350** can be, independently, the same or different. The skewed apertures **350** may aid in the dispersion of a liquid. In addition, the diameter of the first member **320** can be a function of the diameter and the pitch of downcomers of the tray **220**. The ratio of the diameter **342** of the second surface **340** of the first member **320** to the diameter **352** of one of the at least one aperture **350** can be about 10:1-about 45:1, preferably about 20:1-about 25:1. In this exemplary embodiment, the diameter **332** of the first surface **330** to the diameter **342** of the second surface **340** can be about 1:1.1-about 1:4, preferably about 1:1.5-about 1:3, and optimally about 1:2.

The second member **360** can be a substantially cylindrical shape **364**, although the second member **360** can form any suitable shape, and form at least one slot **368**. In this exemplary embodiment, the second member **360** can form three slots **368**, although any number of one or more slots **368** can be formed. Each slot **368** can be, independently, the same or different, but are preferably the same. Typically, the second member **360** is adapted to couple the bottom end **266** of the downcomer **262**. Particularly, the downcomer **262** can have one or more screws or other type of mechanical fastener projecting from its bottom end **266** that is received within a respective slot **368** for coupling of the sprayer **310** thereto. Alternatively, the second member **360** can couple the downcomer **262** using any suitable means, such as welding.

In addition, at least one leg or plurality of legs **380** can couple the first member **320** and the second member **360**. Preferably, the plurality of legs **380** can include a first leg **382**, a second leg **384**, a third leg **386**, and a fourth leg **388**, although any number of one or more legs **380** can be utilized. Each leg **380** can have a respective length **390**, and may be the same or different. Typically, the first member **320**, the second member **360**, and the plurality of legs **380** are formed integrally together by any suitable means, such as welding. The length **390** of a single leg **380** to a diameter **342** of the second surface **340** can have a leg length:diameter ratio of about 1:2-about 1:15, preferably about 1:5-about 1:10, and optimally about 1:7.

Generally, the spray device **310** is designed to couple with any suitable downcomer **262**. Particularly, the sprayer **310** can be coupled onto several kinds of downcomers. Moreover, the sprayer **310** may be designed to minimize the pressure drop through the downcomer, while discharging a dispersed spray of liquid droplets. The unique geometric features of the sprayer **310**, such as the frustum-shaped first member **320**, the



## 5

serrated edge **348**, and the diverging plurality of apertures **350**, can facilitate the dispersion of liquid without substantially increasing the pressure. In addition, generally the frustum **322** shape of the first member **320** further aids the dispersion of liquid. This combination of features may ensure the spread and dispersion of a fluid to the packed bed **400** below. The dimensions of the first member **320**, the number of apertures **350** and their angular orientation, the number of serrations along the serrated edge **348**, and the diameter and angle of the frustum **322** can all be designed to optimize spray patterns to overlap the spray of neighboring sprayers for obtaining a sufficient liquid distribution, even in the event of a sprayer becoming dysfunctional due to, e.g., plugging. Thus, these dimensions can be designed to provide a broad distribution of an umbrella-shaped film or spray.

In operation, the feed collected on the tray **220** may rise and pass through the opening **264** of the downcomer **262**. Afterwards, the fluid can enter the first sprayer **310** proximate to the second member **360**. The first member **320** is spaced apart from the second member **360** so the fluid can fall freely to the first surface **330** of the first member **320**. As a result, the fluid can gain momentum, and upon impingement, the fluid may form a broad film or droplet spray. The overlapping of films and/or sprays from neighboring sprayers can provide a high uniformity of distribution.

## EXAMPLES

The following examples are intended to further illustrate the disclosed embodiments. These illustrations of the embodiments are not meant to limit the claims to the particular details of these examples. These examples can be based on engineering calculations and actual operating experience with similar processes.

The following experiment can demonstrate the effectiveness of the sprayer disclosed herein by quantitatively measuring the spatial spread of a fluid, such as a liquid, dispersed from the sprayer. The discharged liquid can be collected over a specified area underneath the sprayer. Discharge fractions may be collected in subdivided areas and used to assess the effectiveness of the sprayer.

Referring to FIG. 6, a collection apparatus **500** can be positioned underneath a tubular downcomer **562** depicted in phantom. The collection apparatus **500** can be one or more tubes **510** including three concentric tubes **520**, **530**, and **540** of generally incrementally increasing diameter placed directly underneath the downcomer **562**. The tube **520** has a 13 centimeter (cm) diameter and fashioned from a schedule **40** pipe, the tube **530** has a 20 cm diameter and fashioned from a schedule **80** pipe, and the tube **540** has a 25 cm diameter and fashioned from a schedule **40** pipe. Each tube **510** can be 46 cm long to provide a collection volume. These tubes **510** create four zones, namely a Zone A inside the tube **520**, a Zone B between the tubes **520** and **530**, a Zone C between the tubes **530** and **540**, and a Zone D outside the tube **540**. The collection area for each of the Zones A, B, and C is about 130 square cm. The lower end of each tube **510** can be closed by a plate forming three discharging orifices corresponding to each of the Zones A, B, or C. The orifices can be calibrated to discharge a certain amount of liquid, e.g. water, depending on the head of the collected water inside each Zone A, B, or C. The flow rates can be calculated by measuring the height of the water in each Zone A, B, or C by means of a differential pressure gauge connected to pressure ports on the lower end of each respective tube **510**.

The distributor setting on a tray has a triangular pitch of about 11 cm. The spray from the downcomer may extend

## 6

beyond the outermost tube **540**. The amount of water in Zone D is calculated by subtracting the amounts of water in Zones A-C from the amount of water passed through the downcomer **562**.

It is generally desired that a downcomer provides an even distribution of a fluid so that the amounts collected in Zones A, B, C, and D are about equal. Thus, the even distribution of a fluid, such as water, in all four zones would generally be a preferred characteristic of a downcomer.

Referring to FIG. 7, distribution patterns are compared of a splash plate coupled to the downcomer **562**, a sprayer **310** as depicted in FIGS. 1-5 coupled to the downcomer **562**, and the downcomer **562** with no terminal sprayer. The splash plate can be connected to a cuff and spaced about 1.5 cm from the cuff's lower end. The splash plate can be circular in shape having a smooth edge and with a diameter of about 11 cm. The splash plate can form **37** evenly-spaced non-diverging holes, i.e. parallel, to a perpendicular axis, and each hole can have a diameter of about 0.5 cm. The second surface **340** of the sprayer **310** can have a diameter of about 11 cm. Approximately equal amounts of water are provided in the downcomer **562** for testing with the splash plate, the sprayer **310**, and no sprayer. As depicted in FIG. 7, the collected flow rate in liters per minute (lpm) is compared at each zone for the downcomer **562** having the splash plate, the sprayer **310**, and no sprayer. The splash plate distributes liquid in a pattern that is reminiscent of an umbrella, namely a central stream in zone A and droplets dispersed into zone D. There is little or no distribution in zones B and C. The sprayer **310** provides more evenly spaced distribution over the space continuum, with relatively significant amounts in Zones A, B, and D and a small amount in Zone C. The downcomer **562** absent a sprayer distributes almost all the water in Zone A.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The preceding preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.

The invention claimed is:

1. A sprayer for distributing at least one fluid in a vessel comprising a first member having a first surface and a second surface forming at least one aperture therethrough wherein the at least one aperture is skewed with respect to a substantially vertical axis passing through a center of the first member for distributing the at least one fluid in the vessel wherein the first surface and the second surface are substantially parallel and wherein the second surface forms a serrated edge about a perimeter.

2. The sprayer according to claim 1, wherein the perimeter is substantially circular.

3. A sprayer for distributing at least one fluid in a vessel comprising:

a) a first member having a first surface and a second surface forming at least one aperture therethrough wherein the at least one aperture is skewed with respect to a substantially vertical axis passing through a center of the first member for distributing the at least one fluid in the vessel; and

**7**

b) a second member coupled to the first member wherein the first and second members are spaced apart, and wherein the second member is substantially cylindrically shaped.

4. The sprayer according to claim 3, wherein the second member forms at least one slot. 5

5. The sprayer according to claim 4, further comprising at least one leg coupling the first member to the second member.

6. The sprayer according to claim 5, further comprising a plurality of legs. 10

7. The sprayer according to claim 6, wherein the at least one aperture comprises a plurality of apertures wherein the plurality of apertures diverges from the axis.

8. The sprayer according to claim 7, wherein the second surface of the first member forms a serrated edge about a perimeter. 15

**8**

9. A vessel for distributing at least one fluid comprising:

a) a distributor wherein the distributor comprises:

i) a tray forming at least one void;

ii) a conduit coupled to the tray about the void and passing therethrough; and

iii) a sprayer coupled proximate to a bottom end of the conduit wherein the sprayer comprises a first member forming a plurality of diverging apertures there-through and comprising a first surface and a second surface wherein the first surface and the second surface are substantially parallel, and the second surface forms a serrated edge about a perimeter; and

b) a packed bed comprising a plurality of particles positioned below the distributor.

\* \* \* \* \*